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The Back End of the Fuel Cycle Moves Front and Center

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The Back End of the Fuel Cycle Moves Front and Center

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Abstract - *For many years, the commercial nuclear business has remained relatively stable in many ways. The introduction of new plants, the spread to new countries, and the development of key elements of the fuel cycle such as enrichment, reprocessing and waste disposal have been quite modest. That is unlikely to be the case in the coming years. A number of events and trends are becoming increasingly apparent and are cause for both opportunity and caution:*

- *New nuclear power plant orders are likely to grow and spread, particularly in the developing world, e.g. China and India.*
- *The growing recognition that the developing world will be a major competitor for limited energy resources is raising awareness in the developed world regarding concerns for future energy security.*
- *Clearer evidence of the effects of greenhouse gas emissions on global warming, largely from the burning of fossil fuels, is creating more attention on the environmental benefits of nuclear power.*
- *The last decade has shown unequivocal evidence of countries lying, cheating on their NPT obligation, and covertly carrying out nuclear weapons-related activities. Some have suggested their presumed need for a domestic nuclear fuel cycle as a rationale to pursue enrichment and/or reprocessing capabilities, which would move them to the doorstep of being nuclear weapons capable. The DPRK even took the action to abrogate the NPT to hold on to its nuclear weapons program.*
- *9/11 and other evidence have made it undeniable that terrorist groups would like to obtain weapons of mass destruction, particularly nuclear weapons, and would use them if they could.*

A number of initiatives have been proposed recently[1] to allow for the growth and spread of nuclear power while limiting the justifications for additional countries to pursue the acquisition of enrichment or reprocessing capabilities. Most of these initiatives have fresh fuel assurance as a central component. The rationale is simple; if a country can have assurance that it will receive all the fresh fuel it needs for the lifetime of its nuclear power plants, there should be no reason for it to pursue the difficult and costly capability to enrich the fuel itself or to reprocess its spent fuel to recover the produced plutonium for recycle as a fuel in its reactors.

However, such offers are unlikely to be fully persuasive if they are not connected to complementary offers for management of the spent nuclear fuel that is created during power production. In this paper, we discuss the complexity of the linkage to spent fuel take-back and the challenges and opportunities this present to nations' repository programs.

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[1] *M. Elbaradei, The Economists, 16 October 2003.*
The US President Bush's Speech to the National Defense University, 11 February 2004.
INFCIRC/640 – Multi-National Approaches (MNA) to the Nuclear Fuel Cycle, 22 February 2005.
J. S. Choi and T. H. Isaacs, "Toward a New Nuclear Regime," Proceedings of ICAPP 2003, May 2003
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Introduction

For many years, the commercial nuclear business has remained relatively stable in many ways. That is unlikely to be the case in the coming years.

While some countries have called for the phase out of nuclear power and others have ordered a small number of new plants, the overall profile of the nuclear power business has changed little. The number of countries with nuclear power plants is not much different than 10 years ago and the total number of operating plants has increased only slightly. Commercial enrichment and reprocessing services have remained the province of a few countries and consortia. Repository programs have moved forward slowly in some cases, backward in others, with a very small number making substantial progress.

We are now witnessing the beginnings of serious change, with significant consequences for the future nuclear regime. Business as usual will not be the business of the future. The way the nuclear and policy community respond will have much to do with energy adequacy, national security, international stability, and environmental consequences including waste management and disposal.

A number of events and trends are becoming increasingly apparent and are cause for both opportunity and caution:

- New nuclear power plant orders are likely to grow and spread, particularly in the developing world, e.g. China and India.
- The growing recognition that the developing world will be a major competitor for limited energy resources is raising awareness in the developed world regarding concerns for future energy security.
- Clearer evidence of the effects of greenhouse gas emissions on global warming, largely from the burning of fossil fuels, is creating more attention on the environmental benefits of nuclear power.
- The last decade has shown unequivocal evidence of countries lying, cheating on their NPT obligation, and covertly carrying out nuclear weapons-related activities. Some have suggested their presumed need for a domestic nuclear fuel cycle as a rationale to pursue enrichment and/or reprocessing capabilities, which would move them to the doorstep of being nuclear weapons capable. The DPRK even took the action to abrogate the NPT to hold on to its nuclear weapons program.
- 9/11 and other evidence have made it undeniable that terrorist groups would like to obtain weapons of mass destruction, particularly nuclear weapons, and would use them if they could.

A number of initiatives have been proposed recently[1,2,3,4,5,6] to allow for the growth and spread of nuclear power while limiting the justifications for additional countries to pursue the acquisition of enrichment or reprocessing capabilities. Enrichment or reprocessing are the only ways for countries to gain the indigenous capability to transform natural

materials and fuel for and from nuclear power plants to directly weapons-usable materials.

Most of these initiatives have fresh fuel assurance as a central component. The rationale is simple; if a country can have assurance that it will receive all the fresh fuel it needs for the lifetime of its nuclear power plants, there should be no reason for it to pursue the difficult and costly capability to enrich the fuel itself or to reprocess its spent fuel to recover the produced plutonium for recycle as a fuel in its reactors.

While such guarantees face institutional, political, and economic hurdles, they could be overcome. For example, U.S. Secretary of Energy Bodman recently offered 17 tons of high enriched uranium to be blended into fuel grade low enriched uranium as a good faith gesture to create a "fuel reserve" that would be available in the event of supply disruption[7].

However, such offers are unlikely to be fully persuasive if they are not connected to complementary offers for management of the spent nuclear fuel that is created during power production. Most countries have had issues associated with spent fuel storage and almost all have faced substantial problems in making progress on ultimate waste disposal, with or without reprocessing. Table 1 lists the waste management programs in 16 major nuclear power countries. These countries combined have more than 85% of the total global civilian nuclear reactors, and operate more than 93% of the total global civilian nuclear capacities. About half of the 16 countries listed in Table 1 have spent fuel reprocessing as their back-end fuel cycle policies.

The process of selecting appropriate deep geological repositories among several of these countries is now under way. Finland and Sweden are well advanced with plans and site selection for direct disposal of spent fuel, since their Parliament decided to proceed on the basis that it was safe, using existing technology. The US has opted for a final repository in Yucca Mountain, Nevada. However, the process of license application has been delayed due to legislative, legal, and perhaps, technical challenges. The recent USDOE initiative on Global Nuclear Energy Partnership (GNEP)[8] includes the research and development on advanced separation process, and could revive the country's interest on spent fuel reprocessing.

Spent Fuel Take-Back

Currently, about half the countries producing nuclear power (14 of 30) have five or fewer plants and operate less than 7% of global civilian nuclear capacities. These countries may have limited resources to develop their own spent fuel storage and repository disposal systems, and hence, making their pursuit of national programs for long-term waste storage and permanent disposal politically and economically problematic. A regional or multi-national approach to long-term spent fuel management and waste disposal could be an attractive option.

Table 1 Waste Management Programs in Major Nuclear Power Countries

Country	#of Reactor (Capacity, GWe)	Policy	Facilities and progress towards final repositories
Belgium	7 (5.8)	Reprocessing	Central waste storage & underground laboratory established Construction of repository to begin about 2035
Canada	18 (12.6)	Direct Disposal	Underground repository laboratory established Repository planned for use after 2025
China	9 (6.6)	Reprocessing	Central spent fuel storage in LanZhou Site selection studies underway for deep repository in BeiShan
Finland	4 (2.7)	Direct Disposal	Spent fuel storages in operation Low & intermediate-level repositories in operation since 1992 Site near Olkiluoto selected for deep repository for spent fuel
France	59 (63.3)	Reprocessing	Two facilities for storage of short-lived wastes Site selection studies underway for deep repository for commissioning after 2020
Germany	17 (20.3)	Reprocessing but moving to direct disposal	Low-level waste sites in use since 1975 Intermediate-level wastes stored at Ahaus Spent fuel storage at Ahaus and Gorleben High-level repository to be operational after 2010
India	15 (3.0)	Reprocessing	Research on deep geological disposal for HLW
Japan	56 (47.8)	Reprocessing	Low-level waste repository in operation High-level waste storage facility at Rokkasho-mura since 1995 Investigations for deep geological repository site begun
Russia	31 (21.7)	Reprocessing	Sites for final disposal under investigation Central repository for low and intemediate-level wastes (ILW) planned for 2008
South Korea	20 (16.8)	Direct Disposal	Central interim HLW store planned for 2016 Central low- & ILW repository planned for 2008 Investigating deep HLW repository sites
Spain	9 (7.6)	Direct Disposal	Low & intermediate-level waste repository in operation Final HLW repository site selection program planned for 2020.
Sweden	10 (8.9)	Direct Disposal	Central spent fuel storage facility in operation since 1985 Final repository for low to intermediate waste in operation since 1988 Underground research laboratory for HLW repository Site selection for repository in two volunteered locations
Switzerland	5 (3.2)	Reprocessing	Central interim storage for high-level wastes at Zwilag since 2001 Central low and intermediate-level storages operating since 1993 Underground research laboratory for high-level waste repository, with deep repository to be completed by 2020.
Ukraine	15 (13.1)	Undecided	Spent VVER-1000 fuel assemblies are sent to Russia for storage and perhaps, for reprocessing in some later date.
United Kingdom	23 (11.9)	Reprocessing	Low-level waste repository in operation since 1959. High-level waste is vitrified and stored at Sellafiled Underground HLW repository planned.
USA	104 (99.2)	Direct Disposal	Three low-level waste sites in operation Waste Isolation Pilot Plant in operation for defense TRU wastes 2002 decision to proceed with geological repository at Yucca Mountain

Main sources:

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However, for a country pursuing its own national repository program, there is a perceived fear that just the mention of the regional or multi-national repository could jeopardize its own national repository program.

Thus, to allay such fear, the idea of spent fuel take-back arises and is gaining visibility as part of a new nuclear regime[4] that could address the front-end and back-end of the fuel cycle simultaneously. If it becomes possible to offer countries both fresh fuel assurances and guarantees of spent fuel take-back (or take-away, since it is not necessary that it be returned to the same country) it may be possible to provide the mechanism for countries that currently do not have nuclear power to take full advantage of the benefits without the complexity, cost, and political consequences associated with having full fuel cycle capability.

This could tie in nicely with the countries that have small numbers of nuclear power plants who no doubt would rather have their spent fuel and nuclear waste disposed of elsewhere, either in shared regional facilities or in the repositories of countries with major nuclear power programs. The spent fuel take-back should not become a threat to those countries currently developing their own national repositories. For if they decide to taking care of their own spent fuel and wastes, there should not be pressure for them to take other countries' spent fuel and wastes.

So then, who should take other countries' spent fuel back? To begin, the Nuclear Weapons States (NWS) as a group should lead in promoting the "spent fuel take-back" and developing regional or multi-national repository program[9].

The NWS group operates more than half of the world's civilian nuclear reactors, and more than 55% of the world's nuclear electricity generation capacity. It also holds more than half of the global spent fuel and radioactive waste inventories. They have to develop their own repositories and should be capable of providing spent-fuel storage and waste disposal services to other countries within their region. In addition, there is less of a proliferation concern for managing other's spent fuel in the NWS.

The former Soviet Union took spent fuel back from the Soviet-designed reactors located in Eastern Europe and Finland. Currently, the Russian Federation (RF) accepts spent VVER (440 or 1000) fuel from Commonwealth Independent States (CISs) for a fee and on a case-by case basis. Also, the RF has changed its law to allow for import of other countries' spent fuel for storage and processing. And most recently, Russian President Putin called for the creation of an international system of facilities that would provide enrichment and other nuclear fuel cycle related services to other countries that wants nuclear power. He said Russia could establish the enter of such facilities on its soil.[10]

The US initiated the research reactor spent fuel take-back program (FRRSNFA) and supported a similar Russian program (RRRFR) on grounds of non-proliferation. Although it is a different and a more complex issue for public-acceptance, the take-back of power reactor spent fuel from other countries to storage and processing facilities and repositories

in or operated by the NWS is an attractive solution on grounds of global security and non-proliferation.

Not all the NWSs can accept other countries' spent fuel. Notably, France and UK may have geographic constraints in repository siting. A viable solution would be the cooperation among the NWSs, e.g., HLW canisters from France and UK may be shipped and disposed of in a Russian repository. Such cooperation may also help in the disposition of separated fissionable materials, e.g., the disposition of UK's plutonium in French reactors. Also, China may be interested in storing and disposing the spent fuel from Taiwan.

In addition to its large share of nuclear capacities and leadership role in nuclear power development, the NWS group is also the major supplier for nuclear fuel, equipment and services to other non nuclear weapons states (NNWS). It makes a lot of sense for these countries (France, Russia, UK, and the US) would take back the spent fuel while supplying fresh fuel to countries which agree to forgo dangerous and costly fuel cycle facilities.

If the NWS group could set an example in taking back spent fuel, major uranium-producing countries such as Canada, Australia, Kazakhstan and others could also help in disposing spent fuel from other NNWSs. The return of spent fuel to these countries for disposal could benefit their uranium-supply business, in addition to enhancing global security and non-proliferation.

Should such a regime be realized, this would have the important mutual benefit of allowing the growth and spread of nuclear power while simultaneously reducing the incentive or rationale for the spread of either enrichment or reprocessing capabilities. Thus the most sensitive elements in the nuclear fuel cycle that could be misused to support a weapons program would be limited. The spread of global spent fuel storage locations would also be minimized, and as a result, the availability of nuclear materials and the corresponding proliferation risks could be reduced. And countries that decide to pursue such capabilities without an obvious energy related reason would provide an early signal to the rest of the world.

Acceptance of Geologic Repository

Ironically, it is also possible that such a set of initiatives could assist in making national and regional spent fuel or high-level radioactive waste storage and disposal facilities and programs more acceptable (though by no means easy). If a network of such fuel cycle services is offered by those countries currently possessing them, it would add an important national security and international stability dimension to storage and disposal programs.

Repositories, for example, would not be simply dumps for utility spent fuel and wastes; they would be critical elements in a network of fresh fuel assurances and spent fuel take-back that will demonstrably minimize prospects of the misuse of the civilian fuel cycle to

abet steps toward a new nuclear weapons program. And as with enrichment and reprocessing, the number and location of these sensitive facilities would be restricted to a small number, located in those countries with ample experience, capabilities, and the stability to secure them. These security benefits, if properly conducted and communicated, could assist in demonstrating their value to a skeptical public.

Remaining Issue

None of this, of course, should take the place of high priority on securing the existing facilities and materials of greatest concern today. Security of nuclear weapons and the materials that can be used to make them must remain our highest priority wherever they are located. But as we look to the future, the opportunity and, in fact, responsibility exists to shape a new nuclear regime that can simultaneously help meet the energy, security, and waste management challenges better than addressing each aspect separately.

Eisenhower's "Atoms for Peace" speech in 1953, the subsequent creation of the IAEA and the NPT, and continuing export control agreements are among the pillars of the nexus between nuclear power and security. Countries gave up a piece of their sovereignty, for example, and allowed international inspection of their nuclear operations to demonstrate their peaceful intentions. Thus, from the earliest days of nuclear power, the opportunity and the risks were apparent and governmental instruments and international cooperation were seen as essential to augment commercial market mechanisms.

Once again there is a need and an opportunity to augment the market. By investigating cooperative mechanisms, or networks, among leading nuclear nations to serve coming energy needs, the possibility exists to allow for the growth and spread of nuclear power while reducing security and waste management concerns below where they are today.

Conclusion

Global security concerns will arise with the anticipated growth and spread of nuclear power and its associated fuel cycle capabilities. The fissionable materials used in nuclear weapons come from either uranium enrichment or the reprocessing of SNF to extract plutonium. From the beginning of nuclear power the dual use nature of enrichment and reprocessing have been well understood; the same facilities needed to make and process nuclear power reactor fuel can be modified to make weapons usable materials.

Recent initiatives have been proposed by many, including president George Bush and IAEA director general Mohammed ElBaradei, to limit the spread of these sensitive nuclear facilities. A global network to provide assurances of fresh fuel and take back SNF could dramatically reduce or eliminate the need for additional countries to develop their own enrichment or reprocessing capabilities while fully preserving their ability to pursue nuclear power. Russian president Putin recently called for the creation of an international system of facilities that would provide enrichment and other nuclear fuel cycle related services to other countries that wants nuclear power.

Of course, the promise of the return of SNF to the country of origin or to a third country does not eliminate and may heighten the issue of its ultimate disposition. Many features of such an arrangement will have to be carefully defined and developed before an effective international framework can be established. Nevertheless, this approach holds out the possibility of repositories being transformed from perceived waste dumps to integral elements of a security-based international network. The network could include regional or multinational facilities and would provide developing countries with the ability to meet growing energy demand while reducing proliferation and security concerns. Doing the right thing may some day lead to greater public understanding and acceptance of the important role of repositories in realizing a world with adequate energy, environmental integrity, and enhanced security.

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